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PIXEL REORDERING AND SELECTION LOGIC PRIOR TO BUFFERING

RELATED APPLICATIONS

[0001] This application claims priority to Provisional Application for U.S. Patent, App. Ser. No. 60/495,695, entitled "LINE ADDRESS COMPUTER FOR FACILITATING CHROMA CONVERSION", filed August 14, 2003, by Hatti, which is incorporated herein by reference.

[0002] This application is also related to U.S. Patent Application, Serial No. 60/495,301, entitled "PIXEL REORDERING LOGIC FOR MULTIPLE FORMATS IN A FEEDER", filed August 14, 2003, by Hatti, et. al., which is incorporated herein by reference.

[0003] This application is also related to the following U.S. Patent Applications, each of which are incorporated herein by reference:

[0004] "Line Address Computer for Decoding the Line Addresses of Decoded Video Data", U.S. Patent Application Serial No. 10/703,332, filed November 7, 2003 by Hatti, et. al., and claiming priority to Provisional Application for Patent Serial No. 60/495,695.

[0005] "Pixel Reordering and Selection Logic", U.S. Patent Application Serial No. 10/712,482, filed November 13, 2003 by Hatti, et. al., and claiming priority to Provisional Application for Patent Serial No. 60/495,301.

[0006] "Line Address Computer for Providing Coefficients to Chroma Filter", U.S. Patent Application Serial No. 10/712,638, filed November 13, 2003 by Hatti, and claiming priority to Provisional Application for Patent Serial No. 60/495,695.

[0007] "Line Address Computer for Providing Line Addresses in Multiple Contexts", U.S. Patent Application Serial No. 10/714,833, filed November 14, 2003 by Hatti, and claiming priority to Provisional Application for Patent Serial No. 60/495,695.

FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

[0008] [Not Applicable]

[MICROFICHE/COPYRIGHT REFERENCE]

[0009] [Not Applicable]

BACKGROUND OF THE INVENTION

[0005] A video decoder receives encoded video data and decodes and/or decompresses the video data. The decoded video data comprises a series of pictures. A display device displays the frames. The pictures comprise a two-dimensional grid of pixels. The display device displays the pixels of each picture in real time at a constant rate. In contrast, the rate of decoding can vary considerably for different video data. Accordingly, the video decoder writes the decoded pictures in a frame buffer.

[0006] Among other things, a display engine is synchronized with the display device and provides the appropriate pixels to the display device for display. The display engine provides the appropriate pixels from the frame buffer to the display device. The location of the

appropriate pixels in the frame buffer is dependent on the manner that the video decoder writes the picture to the frame buffer.

[0007] Characteristics that characterize the manner that the video decoder writes the picture to the frame buffer include the packing of luma and chroma pixels, the linearity that the picture is stored, and the spatial relationship between the luma and chroma pixels. The foregoing characteristics are usually determined by the original format of the source video data.

[0008] The luma and chroma pixels of a picture can either be stored together or separately. The chroma pixels include chroma red difference pixels Cr, and chroma blue difference pixels Cb. In MPEG, DV25, and TM5, the luma Y pixels are stored in one array, while both chroma pixels Cr/Cb are stored together in another array. In planar, the luma pixels Y are stored in one array, the Cr pixels are stored in a second array, and the Cb pixels are stored in a third array. In packed YUV, the luma pixels and both the chroma Cr/Cb pixels are stored together in a single array.

[0009] In the packed YUV format, each alternating luma Y pixel is co-located with chroma pixels Cr/Cb in the horizontal direction. A picture in the packed YUV format can be divided into units of four pixels, each of the units capable of being stored in a 32-bit word. The four pixels comprise adjacent luma Y pixels and the chroma pixels Cr/Cb co-located with one of the luma Y pixels. The luma Y pixels and the chroma pixels Cr/Cb can be packed in any one of several pixel orders. Examples of pixel orders that the luma Y pixels and chroma pixels Cr/Cb can be packed include, (Cb_0, Y_0, Cr_0, Y_1) , (Cr_0, Y_0, Cb_0, Y_1) , (Y_0, Cb_0, Y_1, Cr_0) , and (Y_0, Cr_0, Y_1, Cb_0) . Additionally, in big endian order, the four

bytes are stored in a 32-bit dword as (byte0,byte1,byte2,byte3). In little endian order, the four bytes are stored as byte3/byte2/byte1/byte0. Whether bytes are stored in big endian byte order or little endian byte order depends on the system endianness.

[0010] The video decoder does not necessarily store the picture in a linear manner. In planar and packed YUV, the video decoder stores pictures in left to right and top to bottom order in the memory. However, in MPEG, DV25, and TM5, pictures are stored in the frame buffer in a macroblock format. In the macroblock format, the pixels of the picture are divided into two dimensional blocks. The video decoder stores the two dimensional blocks in consecutive memory locations.

[0011] Additionally, the spatial relationship of chroma pixels to luma pixels can differ among the many standards. Standards defining the spatial relationship of the chroma pixels to luma pixels include MPEG 4:2:0, MPEG 4:2:2, DV-25 4:2:0, and TM5 4:2:0, to name a few. Where the standards for the display and the decoded video data differ, chroma pixels for the display can be interpolated from two or more chroma pixels in the decoded video data. The chroma interpolation heavily dependent on the format of the source video data.

[0012] Conventionally, after each horizontal synchronization pulse, the host processor calculates the address of the first pixels of a line and the parameters for chroma format conversion. The host processor then programs the display engine with the foregoing.

[0013] Programming the display engine at each horizontal synchronization pulse consumes considerable bandwidth from the host processor.

[0014] Further limitations and disadvantages of conventional and traditional approaches will become apparent to one of skill in the art, through comparison of such systems with embodiments presented in the remainder of the present application with references to the drawings.

BRIEF SUMMARY OF THE INVENTION

[0015] Presented herein is a line address computer for calculating the line addresses of decoded video data.

[0016] In one embodiment, there is presented a method for displaying pictures. The method comprises fetching a portion of a picture stored in a frame buffer, the portion of the picture being stored with a byte order, converting the byte order of the portion of the picture to a predetermined byte order, the byte order being different from the predetermined byte order, and storing the portion of the picture in another buffer with the predetermined byte order.

[0017] In another embodiment, there is presented a system for displaying pictures. The system comprises a first circuit, a second circuit, and a buffer. The first circuit fetches a portion of a picture stored in a frame buffer, the portion of the picture being stored with a byte order. The second circuit converts the byte order of the portion of the picture to a predetermined byte order, the byte order being different from the predetermined byte order. The buffer stores the portion of the picture with the predetermined byte order.

[0018] In another embodiment, there is presented a method for displaying pictures. The method comprises fetching a portion of a picture stored in a frame buffer, the portion of the picture being stored with a pixel order, converting the pixel order of the portion of the picture to a predetermined pixel order, and storing the portion of the picture in another buffer with the predetermined pixel order.

[0019] In another embodiment, there is presented a system for displaying pictures. The system comprises an

input data write unit, a circuit, and a buffer. The input data write unit fetches a portion of a picture stored in a frame buffer, the portion of the picture being stored with a pixel order. The circuit converts the pixel order of the portion of the decoded picture to a predetermined pixel order. The buffer portion of the picture with the predetermined pixel order.

[0020] In another embodiment, there is presented a method for displaying pictures. The method comprises fetching a portion of a picture stored in a frame buffer, said portion of the picture comprising a plurality of pixels, storing luma pixels in a luma pixel register, if the plurality of pixels comprise luma pixels, storing chroma pixels in a chroma pixel register, if the plurality of pixels comprise chroma pixels, and storing the contents of the chroma pixel register in one portion of another buffer and the contents of the luma pixel register in another portion of the another buffer.

[0021] In another embodiment, there is presented a system for displaying pictures. The system comprises a first circuit, a luma pixel register, a chroma pixel register, and another buffer. The first circuit fetches a portion of a picture stored in a frame buffer, the portion of the picture comprising a plurality of pixels. The luma pixel register stores luma pixels, if the plurality of pixels comprise luma pixels. The chroma pixel register stores chroma pixels, if the plurality of pixels comprise chroma pixels. The another buffer stores the portion of the picture.

[0022] These and other advantages and novel features of the present invention, as well as details of an illustrated

embodiment thereof, will be more fully understood from the following description and drawings.

BRIEF DESCRIPTION OF SEVERAL VIEWS OF THE DRAWINGS

[0023] **FIGURE 1** is block diagram of an exemplary decoder system in accordance with an embodiment of the present invention;

[0024] **FIGURE 2** is a block diagram of an exemplary frame;

[0025] **FIGURE 3A** is a block diagram of a frame buffer storing a frame in accordance with the MPEG, DV25 and TM5 formats;

[0026] **FIGURE 3B** is a block diagram of a frame buffer storing a frame in accordance with the packed YUV format;

[0027] **FIGURE 3C** is a block diagram of a frame buffer storing a frame in accordance with the planar format;

[0028] **FIGURE 4A** is a block diagram of an exemplary gword storing packed YUV data in big endian byte order;

[0029] **FIGURE 4B** is a block diagram of an exemplary gword storing packed YUV data in little endian byte order;

[0030] **FIGURE 5A** is a block diagram of an exemplary gword storing MPEG/DV-25/TM5 pixels in big endian byte order;

[0031] **FIGURE 6** is a block diagram of an exemplary display engine in accordance with an embodiment of the present invention;

[0032] **FIGURE 7** is a block diagram of a pixel feeder in accordance with an embodiment of the present invention;

[0033] **FIGURE 8** is a block diagram of the luma/chroma pixel separator and Gword packer in accordance with an embodiment of the present invention;

[0034] **FIGURE 9** is a block diagram of an endian swizzle in accordance with an embodiment of the present invention; and

[0035] **FIGURE 10** is a block diagram of pixel select logic in accordance with an embodiment of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

[0036] Referring now to **FIGURE 1**, there is illustrated a block diagram of an exemplary decoder system for decoding compressed video data, configured in accordance with an embodiment of the present invention. A processor, that may include a CPU 90, reads transport stream 65 into a transport stream buffer 32 within an SDRAM 30.

[0037] The data is output from the transport stream buffer 32 and is then passed to a data transport processor 35. The data transport processor 35 then demultiplexes the transport stream 65 into constituent transport streams. The constituent packetized elementary stream can include for example, video transport streams, and audio transport streams. The data transport processor 35 passes an audio transport stream to an audio decoder 60 and a video transport stream to a video transport processor 40.

[0038] The video transport processor 40 converts the video transport stream into a video elementary stream and provides the video elementary stream to a video decoder 45. The video decoder 45 decodes the video elementary stream, resulting in a sequence of decoded video frames. The decoding can include decompressing the video elementary stream. It is noted that there are various standards for compressing the amount of data required for transportation and storage of video data, such as MPEG-2 for example.

[0039] The decoded video data includes a series of frames. The frames are stored in a frame buffer 48. The frame buffer 48 can be dynamic random access memory (DRAM) comprising 128 bit/16 byte gigantic words (gwords). It is also noted that in certain standards, such as MPEG-2, the order that pictures are decoded is not necessarily the

order that pictures are presented. Accordingly, several pictures can be stored in the frame buffer 48 at a given time.

[0040] The display engine 50 is responsible for providing a bitstream to a display device, such as a monitor or a television. A display device displays the pictures in a specific predetermined display format with highly synchronized timing. The format dictates the order that different portions of a picture are displayed, as well as the positions of pixels.

[0041] Referring now to **FIGURE 2**, there is illustrated a block diagram describing an exemplary frame 100. The frame 100 comprises any number of horizontal rows 100(0)...100(N). Each row 100(0)...100(N) includes a row of luma Y pixels, $Y_0...Y_x$, and half as many chroma Cr pixels $Cr_0...Cr_{(x-1)/2}$ and half as many chroma Cb pixels $Cb_0...Cb_{(x-1)/2}$. In a standard definition television frame 100, there are 480 rows ($N=479$), each comprising 720 luma Y pixels, 360 chroma Cr pixels, and 360 chroma Cb pixels.

[0042] The luma Y, chroma Cr, and chroma Cb pixels can be stored in one of several array formats. For example, in the packed YUV format, the luma Y, chroma Cr, and chroma Cb pixels are stored together in one array. In the planar format, the luma pixels, chroma Cr pixels, and chroma Cb pixels are each stored in separate arrays. In MPEG, DV25, and TM5, the luma pixels Y are stored in one array, while the chroma Cr and chroma Cb pixels are stored together in another array.

[0043] Referring now to **FIGURE 3A**, there is illustrated a block diagram describing the frame buffer storing the frame 100 in accordance with an array format for the MPEG, DV25 and TM5 formats. The frame buffer 48 comprises two

arrays 48Y, 48C of 16 byte/128 bit gwords 48Y(0), 48Y(1), 48Y(2),... , and 48C(0), 48C(1), 48C(2),.... The pixels luma pixels Y are stored in array 48Y. The chroma Cr and Cb pixels are stored in array 48C. The gwords 48Y(0), 48Y(1),... each store 16 horizontally adjacent luma pixels, $Y_{16i} \dots Y_{16i+15}$. Each gword in array 48Y is associated with a gword in array 48C, wherein the associated gword in array 48C stores the chroma Cr and chroma Cb pixels co-located with the luma pixels $Y_{16i} \dots Y_{16i+15}$.

[0044] Referring now to **FIGURE 3B**, there is illustrated a block diagram describing the frame buffer 48 storing frame 100 in accordance with the packed YUV array format. The frame buffer 48 comprises 16 byte/128 bit gwords 48(0), 48(1), 48(2),... . The pixels $Y_0 \dots Y_x$, $Cr_0 \dots Cr_{(x-1)/2}$ in each row of the frame 100(0)...100(N) are divided into units of four pixels $U_0 \dots U_{(x-1)/2}$. Each unit U_i comprises two luma pixels Y_{2i} and Y_{2i+1} , and the chroma Cr_i and chroma Cb_i pixels co-located with luma pixels Y_{2i} . The units U of each row 100(0)...100(N) are stored from left to right $U_0 \dots U_{(x-1)/2}$ in consecutive four byte memory portions. The gwords 48(0), 48(1),... can store four units U_{4i} , U_{4i+1} , U_{4i+2} , U_{4i+3} , therein. The four pixels Y_{2i} , Y_{2i+1} , Cr_i , Cb_i can be stored into four bytes in one of pixel orders, including, Cb_i Y_{2i} Cr_i Y_{2i+1} , Cr_i Y_{2i} Cb_i Y_{2i+1} , Y_{2i} Cr_i Y_{2i+1} Cb_i , and Y_{2i} Cb_i Y_{2i+1} Cr_i .

[0045] Referring now to **FIGURE 3C**, there is illustrated a block diagram describing the frame buffer 48 storing frame 100 in accordance with the planar format. The frame buffer 48 comprises three arrays 48Y, 48CR, 48CB of 16 byte/128 bit gwords 48Y(0), 48Y(1), 48Y(2),... , and 48C(0), 48C(1), 48C(2),.... The luma pixels Y are stored in array 48Y. The chroma Cr are stored in array 48CR. The chroma Cb pixels are stored in array 48CB. The gwords 48Y(0),

48Y(1),... each store 16 horizontally adjacent luma pixels, $Y_{16i}...Y_{16i+15}$. Each gword in array 48Y is associated with a gword half in array 48CR, and a gword half in array 48CB, wherein the associated gword half in array 48CR and array 48CB store the chroma Cr and chroma Cb pixels co-located with the luma pixels $Y_{16i}...Y_{16i+15}$.

[0046] The pixels can either be written in big endian byte order, byte0,byte1,byte2,byte3 or little endian byte order byte3,byte2,byte1,byte0.

[0047] Referring now to **FIGURE 4A**, there is illustrated a block diagram of an exemplary gword 48(i) storing data in big endian byte order. The gword 48(i) comprises 128 bits, $b_{127}...b_0$. In big endian byte order, bytes are stored starting from bits $b_{127}...b_{120}$. The units U_{4i} , U_{4i+1} , U_{4i+2} , U_{4i+3} are stored in bits $b_{127}...b_{96}$, $b_{95}...b_{64}$, $b_{63}...b_{32}$, $b_{31}...b_0$, respectively. Additionally, the first, second, third, and fourth pixel of unit U_{4i+3} are stored in bits $b_{31}...b_{24}$, $b_{23}...b_{16}$, $b_{15}...b_8$, and $b_7...b_0$, respectively. If the pixels of units U_{4i} , U_{4i+1} , U_{4i+2} , U_{4i+3} are in the pixel order Cb_0, Y_0, Cr_0, Y_1 , the chroma Cb pixels in units U_{4i} , U_{4i+1} , U_{4i+2} , U_{4i+3} are stored in bits $b_{103}...b_{96}$, $b_{71}...b_{64}$, $b_{39}...b_{32}$, and $b_7...b_0$ respectively. The first luma pixels (that are co-located with the chroma Cr and Cb pixels) Y_0 of units U_{4i} , U_{4i+1} , U_{4i+2} , U_{4i+3} are stored in bits $b_{111}...b_{104}$, $b_{79}...b_{72}$, $b_{47}...b_{40}$, and $b_{15}...b_8$, respectively. The chroma Cr pixels in units U_{4i} , U_{4i+1} , U_{4i+2} , U_{4i+3} are stored in bits $b_{119}...b_{112}$, $b_{87}...b_{80}$, $b_{55}...b_{48}$, and $b_{23}...b_{16}$, respectively. The second luma pixels (that are co-located with the chroma Cr and Cb pixels) Y_1 of units U_{4i} , U_{4i+1} , U_{4i+2} , U_{4i+3} are stored in bits $b_{127}...b_{120}$, $b_{95}...b_{88}$, $b_{63}...b_{56}$, and $b_{31}...b_{24}$, respectively.

[0048] Referring now to **FIGURE 4B**, there is illustrated a block diagram of an exemplary gword 48(i) storing data in little endian byte order. The gword 48(i) comprises 128

bits, $b_{127}...b_0$. In little endian byte order, bytes are stored starting from bits $b_{127}...b_{120}$. The units U_{4i} , U_{4i+1} , U_{4i+2} , U_{4i+3} are stored in bits $b_{127}...b_{96}$, $b_{95}...b_{64}$, $b_{63}...b_{32}$, $b_{31}...b_0$, respectively. Additionally, the first, second, third, and fourth pixel of unit U_{4i} are stored in bits $b_{127}...b_{120}$, $b_{119}...b_{112}$, $b_{111}...b_{104}$, are $b_{103}...b_{96}$, respectively. If the pixels of units U_{4i} , U_{4i+1} , U_{4i+2} , U_{4i+3} are in the pixel order Cb, Y_0, Cr, Y_1 , the chroma Cb pixels in units U_{4i} , U_{4i+1} , U_{4i+2} , U_{4i+3} are stored in bits $b_{103}...b_{96}$, $b_{71}...b_{64}$, $b_{39}...b_{32}$, and $b_7...b_0$, respectively. The first luma pixels (that are co-located with the chroma Cr and Cb pixels) Y_0 of units U_{4i} , U_{4i+1} , U_{4i+2} , U_{4i+3} are stored in bits $b_{111}...b_{104}$, $b_{79}...b_{72}$, $b_{47}...b_{40}$, and $b_{15}...b_8$, respectively. The chroma Cr pixels in units U_{4i} , U_{4i+1} , U_{4i+2} , U_{4i+3} are stored in bits $b_{119}...b_{112}$, $b_{87}...b_{80}$, $b_{55}...b_{48}$, and $b_{23}...b_{16}$, respectively. The second luma pixels (that are co-located with the chroma Cr and Cb pixels) Y_1 of units U_{4i} , U_{4i+1} , U_{4i+2} , U_{4i+3} are stored in bits $b_{127}...b_{120}$, $b_{95}...b_{88}$, $b_{63}...b_{56}$, and $b_{31}...b_{24}$, respectively.

[0049] From the foregoing, it can be seen that the 32-bits storing a unit U are different. Additionally, in big endian, the lowest order bits store the first pixel while in little endian, the highest order bits store the first pixel.

[0050] Referring now to **FIGURE 5A**, there is illustrated a block diagram of an exemplary gword 48(i) storing data in big endian byte order. The gword 48(i) comprises 128 bits, $b_{127}...b_0$. In big endian order, bytes are stored starting from bits $b_{127}...b_{120}$. For pixels $Y_{16i}...Y_{16i+15}$, the pixel Y_{16i} is stored in bits $b_{127}...b_{120}$, The pixel Y_{16i+1} is stored in bits $b_{119}...b_{112}$, the pixel Y_{16i+2} is stored in bits $b_{111}...b_{104}$, the pixel Y_{16i+3} is stored in bits $b_{103}...b_{96}$, and the pixel Y_{16i+15} is stored in bits $b_7...b_0$. For pixels $Cr/Cb_{8i}...Cr/Cb_{8i+7}$, the pixel Cb_{8i} is

stored in bits $b_{127}...b_{120}$, pixel Cb_{8i+1} is stored in bits $b_{119}...b_{112}$, pixel Cr_{8i} is stored in bits $b_{111}...b_{104}$, pixel Cr_{8i+1} is stored in bits $b_{103}...b_{96}$, pixel Cb_{8i+7} is stored in bits $b_{23}...b_{16}$, pixel Cr_{8i+7} is stored in bits $b_7...b_0$.

[0051] The display device is usually separate from the decoder system. The display device displays the frames with highly synchronized timing. Each row $100(0)...100(N)$ is displayed at a particular time interval. The display engine 50 provides the pixels to the display device for display, via the video encoder. The display device and the display engine 50 are synchronized by means of a vertical synchronization pulses and horizontal synchronization pulses. When the display device begins displaying a new frame 100 or field, the display device transmits a vertical synchronization pulse. Each time the display device begins displaying a new line $100(x)$, the display device sends a horizontal synchronization pulse. The display engine 50 uses the horizontal and vertical synchronization pulses to provide a bitstream comprising the pixels at a time related to the time for display.

[0052] The display engine 50 generates the bitstream from the decoded pictures stored in the frame buffers 48. To generate the bitstream of the pixels for display on the display device, the display engine 50 fetches the pixels from the frame buffer 48. However, the decoded pictures may be progressive while the display device is interlaced. Additionally, the decoded picture may have chroma pixels in different positions from the display format. Additionally, the pixels of the decoded picture may be stored in a variety of different ways. For example, the chroma pixels can either be stored separately or with the luma pixels.

[0053] Where the decoded picture has a different chroma

format from the display format, the chroma pixels for the chroma pixel positions in the display format are interpolated from the chroma format of the decoded picture.

[0054] Referring now to **FIGURE 6**, there is illustrated a block diagram of the display engine 50 in accordance with an embodiment of the present invention. The display engine 50 includes a scaler 705, a compositor 710, a feeder 715, and a deinterlacing filter 720. The feeder 715 provides a bitstream of the pixels in the order the pixels are displayed for the display device. The bitstream comprises chroma pixels in the chroma pixel positions of the display format.

[0055] Referring now to **FIGURE 7**, there is illustrated a block diagram describing an exemplary feeder 715 in accordance with an embodiment of the present invention. The feeder 715 provides a bitstream comprising pixels for display on the display device. The bitstream provides the pixels for display on the display device at a time related to the time the pixels are to be displayed by the display device. Additionally, the bitstream comprises chroma pixels in the chroma pixel positions in accordance with the display format. After each horizontal synchronization pulse, a row 100(x) is presented to the display device 65 for display.

[0056] After each vertical synchronization pulse, the host processor 90 programs the feeder 715 with the addresses of the frame buffer memory locations storing the first luma pixels, the first chroma pixel(s) for display (i.e., the left most pixels in row 100(0)), and the format of the decoded frame.

[0057] The foregoing parameters are provided to the feeder 715 via the RBUS interface 805. After providing the

parameters to the RBUS interface 805, the host 90 sets a start parameter in the RBUS interface 805.

[0058] The RBUS interface 805 provides the initial starting luma and chroma addresses to the BRM 815. When the BRM 815 receives the starting luma and chroma addresses, the start parameter in the RBUS interface 805 is deasserted. The BRM 815 issues the commands for fetching the luma and chroma pixels in the first line of the frame/field. The IDWU 820 effectuates the commands.

[0059] The BRM 815 includes a command state machine 815a and horizontal address computation logic 815b. The command state machine 815a can issue commands to the IDWU 820 causing the feeder 715 to fetch pixels from the frame buffer at a memory address provided by the command state machine 815a. The command state machine initially commands the IDWU 820 to fetch the pixels starting at the starting luma and chroma addresses. The horizontal computation logic 815b maintains the address of the frame buffer 48 location storing the next pixels in the display order.

[0060] The IDWU 820 comprises an endian swizzle & pixel select logic 820a, a write data path 820b, and a double buffer state machine 820c. The IDWU 820 writes the fetched pixels to a double buffer 840 until the double buffer 840 is full. After the double buffer 840 is full, the double buffer state machine detects when half of the data in the double buffer 840 is consumed. Responsive thereto, the command state machine 815a commands the IDWU 820 to fetch the next pixels in the display order, starting at the address calculated by the horizontal address computation logic 815b, until the double buffer 840 is full. The foregoing continues for each pixel in the first line 100(0).

[0061] A line address computer 810 calculates the address of the memory locations storing the starting pixels of the next line, e.g., line 100(1) if a progressive display or line 100(2) if an interlaced display. The BRM 815 causes the IDWU 820 to start fetching pixels from the provided starting address. For each horizontal synchronization pulse, the line address computer 810 provides the address of the memory locations storing the first pixel (leftmost) of a row of luma pixels. The line address computer 810 provides the address storing the first pixel of consecutive rows of luma pixels 100(0), 100(1),...,100(N) if the display is progressive. The line address computer 810 provides the address storing the first pixel of alternating rows of luma pixels 100(0), 100(2),...,100(N-1), 100(1), 100(3)...100(N) if the display device 65 is interlaced. The line address computer 810 is described in more detail in "Line Address Computer for Calculating the Line Addresses of Decoded Video Data", U.S. Patent Application Serial No. 10/703,332, filed November 7, 2003, by Hatti, et. al. (Attorney Docket No. 15139US01), which is incorporated herein by reference.

[0062] A pixel feeder 835 comprises a chroma filter data path 835b, a chroma line buffer 835c, an output data path 835d, fixed color generation logic 835e, and a double buffer read state machine 835f. The double buffer state machine 835f performs various duties that manage the pixel feeder 835. The duties include maintaining the double-buffer 840 status, reading pixels from the double buffer 840, sequencing the chroma filter datapath 835b, and loading pixels onto the FIFO 830.

[0063] The double buffer read state machine 835f creates a rasterized data stream from the pixel data stored in the

double buffer 840. The stream comprises a luma pixel bitstream and the chroma pixel bitstream(s) that are synchronized with respect to each other, such that the luma pixels in the bitstream at a particular time and the chroma pixels in the bitstream(s) at a particular time are either co-located, or the pixels for interpolating the chroma pixels at chroma pixel positions are co-located with the luma pixels.

[0064] The pixel feeder 835 interpolates chroma pixels for the chroma pixel positions in the display frame from the pixels in the decoded frame. At each horizontal synchronization pulse, the line address computer 810 provides interpolation weights, WCb_T , WCb_B , WCr_T , and WCr_B for interpolation to the chroma filter data path 835b. The interpolation weights depend on the decoded frame format, the display format, and the specific row with the chroma pixel positions.

[0065] A FIFO 830 receives the luma bitstream from the double buffer and a bitstream of interpolated chroma pixels. The FIFO 830 also receives signals from a bus protocol generator 825 to prepare the luma bitstream and interpolated chroma bitstream for transmission over a bus.

[0066] However, as noted above, the pixels of the decoded pictures can have a variety of byte orders, pixel orders, and array formats. In order to interpolate the chroma pixels, the endian select & pixel selection logic 820a places the pixels of the decoded frames into a predetermined byte order, pixel order, and array format prior to storage in the double buffer 840.

[0067] Referring now to **FIGURE 8**, there is illustrated a block diagram of the IDWU 820 in accordance with an embodiment of the present invention. The IDWU 820 includes

a data path comprising endian swizzle 820a(1), pixel select logic 820a(2), a 32-bit luma pixel register 905Y, a 16-bit chroma red pixel register 905R, and a 16-bit chroma blue pixel register 905B.

[0068] The contents of the pixel registers 905 are stored in the double buffer 840. In an exemplary case, the double buffer 840 can include two regions, wherein the contents of pixel register 905Y are stored in one of the regions, and the contents of pixel registers 905B, and 905R are written together and stored in another region.

[0069] Either big endian or little endian byte order can be used for storing the pixels in the double buffer 840. Therefore, the position of each particular pixel within the four bytes depends on whether big endian or little endian byte order is used. For consistent handling, either big endian byte order or little endian order is chosen. Bytes of pixel data in the different or opposite byte order chosen can be reordered. The endian swizzle 820a(1) reverses the ordering of the pixels from either little endian to big endian, or big endian to little endian, when the byte order of the pixels is different or opposite the byte order chosen.

[0070] Because the fetched pixels can include a variety of different pixels therein, the pixel select logic 820a(2) directs the pixels to the appropriate pixel registers 905.

[0071] Referring now to **FIGURE 9**, there is illustrated a block diagram of the endian swizzle 820a(1) in accordance with an embodiment of the present invention. The endian swizzle 820a(1) receives the four pixel/32-bit pixel fetches from the IDWU write path 820b. The 32-bit access is demultiplexed into four bytes B_0 , B_1 , B_2 , and B_3 , each byte corresponding to a pixel. The endian swizzle 820a(1)

includes four multiplexers 1005(0), 1005(1), 1005(2), and 1005(3).

[0072] If a different or opposite byte ordering is used for the pixels, then the byte order chosen, B_0 in the original byte order corresponds to B_3 of the chosen byte order. B_1 in the little endian order corresponds to B_2 of the chosen byte order. B_2 in little endian order corresponds to B_1 of the chosen byte order. B_3 in little endian order corresponds to B_0 of the chosen byte order.

[0073] Accordingly, multiplexers 1005(0) and 1005(3) receive bytes B_0 and B_3 . Multiplexers 1005(1) and 1005(2) receive bytes B_1 and B_2 . If the original byte order is different or opposite the chosen byte order, bytes B_0 and B_3 are swapped and bytes B_1 and B_2 are swapped. Multiplexer 1005(0) selects byte B_3 , multiplexer 1005(1) selects byte B_2 , multiplexer 1005(2) selects byte B_1 , and multiplexer 1005(3) selects byte B_0 . The outputs of the multiplexers 1005 are multiplexed to result in the 32-bit access converted to big-endian byte order, e.g., B_3, B_2, B_1, B_0 . If the original byte order is the same as the chosen byte order, the byte ordering is maintained. Multiplexer 1005(3) selects byte B_3 , multiplexer 1005(2) selects byte B_2 , multiplexer 1005(1) selects byte B_1 , and multiplexer 1005(0) selects byte B_0 . The outputs of the multiplexers 1005 are multiplexed to result in the original 32-bit access, e.g., B_0, B_1, B_2, B_3 . The multiplexers 1005 are controlled by a signal `Byte_In_DW_Rendian_Sel` indicating whether a different or opposite byte order is originally used (1 indicates used, 0 indicates not used, for example) provided by the double buffer read state machine 835f to effectuate the foregoing.

[0074] Referring now to **FIGURE 10**, there is illustrated a block diagram of an exemplary pixel separator & Gword

packer 820b in accordance with an embodiment of the present invention. The pixel separator & Gword packer 820b comprises a pixel separator 820b(1) and a Gword packer 820b(2).

[0075] The pixel separator 820b(1) receives double words B_0 , B_1 , B_2 , and B_3 at stages 820b(1)a, 820b(1)b, 820b(1)c, and 820b(1)d, respectively. The stages 820b(1)a, 820b(1)b, 820b(1)c, and 820b(1)d include a packed YUV circuit and MPEG circuit. Each packed YUV circuit includes a demultiplexers for reordering bytes forming the double words in any one of four different pixel orders, CbYCrY, CrYCbY, YCbYCr, or YCrYCb. The MPEG circuit separates luma pixels from the chroma pixels.

[0076] The Gword packer 820b(2) includes a MPEG luma/chroma packer, planar luma/chroma Cb/chroma Cr packer, and a packed YUV luma & chroma packer. The MPEG luma packer packs 16 luma pixels into a Gword register and MPEG chroma packer packs 8 chroma Cb & 8 chroma Cr pixels in another Gword register, when the format is MPEG. The planar luma packer packs 16 luma pixels into the Gword register and planar chroma packer packs 16 chroma Cb pixels into another Gword register and 16 chroma Cr pixels into separate Gword register, when the format is Planar. The packed YUV Gword packer packs 8 pixels of luma, 4 pixels of chroma Cb and 4 pixels of chroma Cr into the Gword register, when the format is packed YUV. The packed YUV, MPEG, Planar Chroma packer includes a Cb word register and a Cr word register for storing pixels over more than one access.

[0077] One embodiment of the present invention may be implemented as a board level product, as a single chip, application specific integrated circuit (ASIC), or with varying levels integrated on a single chip with other

portions of the system as separate components.

[0078] The degree of integration of the system will primarily be determined by speed and cost considerations. Because of the sophisticated nature of modern processors, it is possible to utilize a commercially available processor, which may be implemented external to an ASIC implementation of the present system.

[0079] Alternatively, if the processor is available as an ASIC core or logic block, then the commercially available processor can be implemented as part of an ASIC device with various functions implemented as firmware.

[0080] While the invention has been described with reference to certain embodiments, it will be understood by those skilled in the art that various changes may be made and equivalents may be substituted without departing from the scope of the invention. In addition, many modifications may be made to adapt particular situation or material to the teachings of the invention without departing from its scope.

[0081] Therefore, it is intended that the invention not be limited to the particular embodiment(s) disclosed, but that the invention will include all embodiments falling within the scope of the appended claims.